Global convective-stratiform rain patterns from space and in GCMs

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Outline

1. Amazon MCSs and the Atlantic Walker Cell

2. ITCZ convective systems related to the shallow meridional overturning and the deeper Hadley circulation in the East Pacific

3. Global convective-stratiform rain patterns from the GPM DPR compared to the Coupled Model Intercomparison Project 5 (CMIP5) models

MCS contribution to Amazonian rain

Probability of IR cluster trajectories (2014-5) TRMM/GPMV5 radar rainfall (1998-2016)
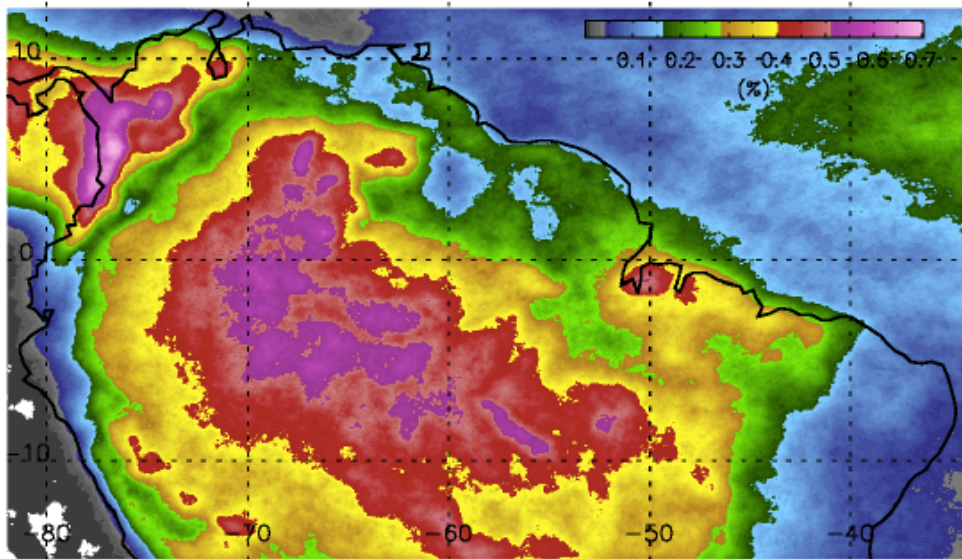
Courtesy of E. Anselmo
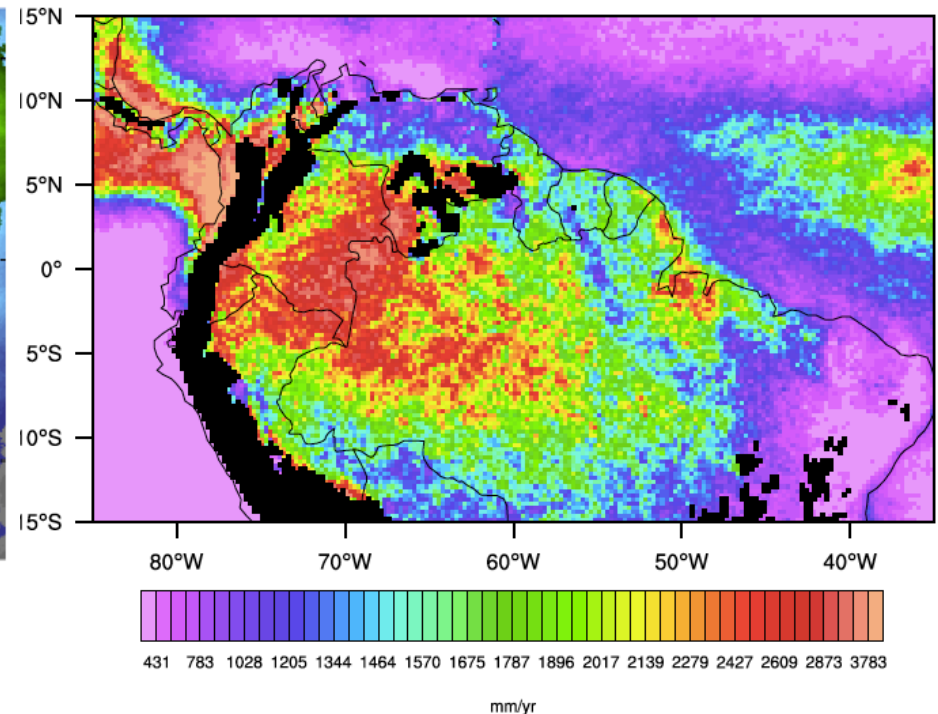
Courtesy of A. Funk

MCSs contribute to a majority of tropical rainfall (e.g., Nesbitt et al. 2006), but high-resolution cloud and rain retrievals highlight a distinct separation between orographic, coastal and central Amazonian systems.
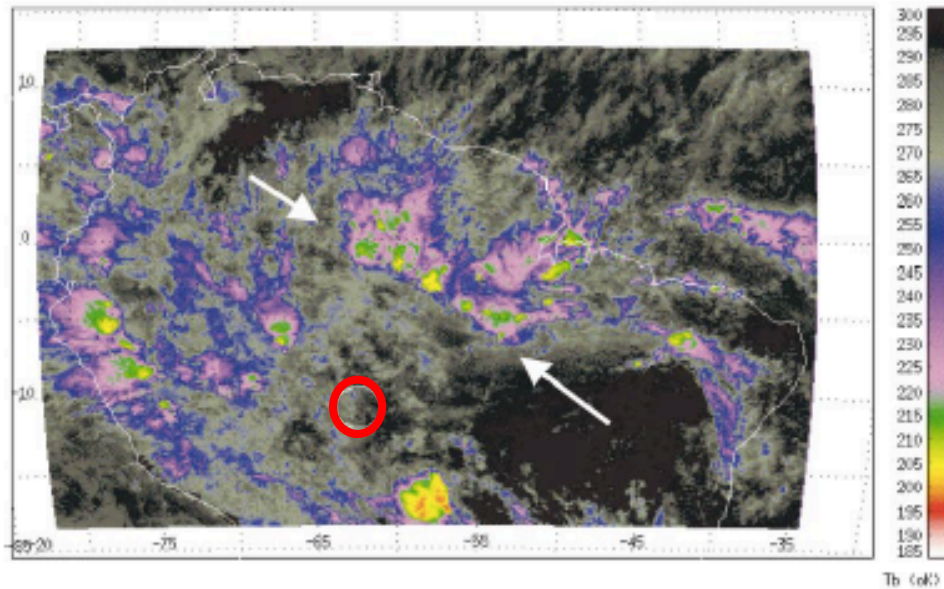
PR/DPR V5 rain type occurrence (1998-2016)

Shallow isolated

Shallow non-isolated
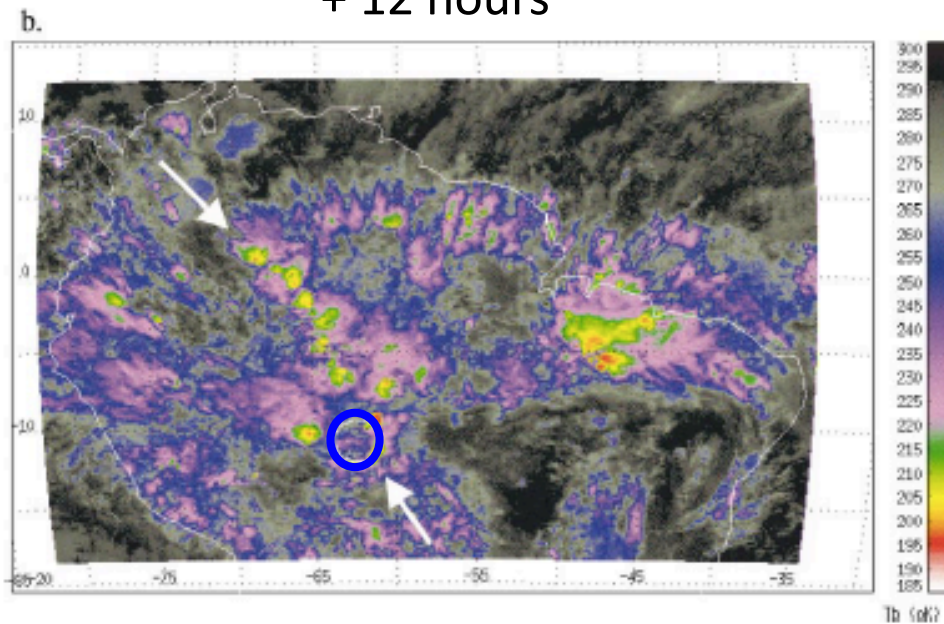

Stratiform
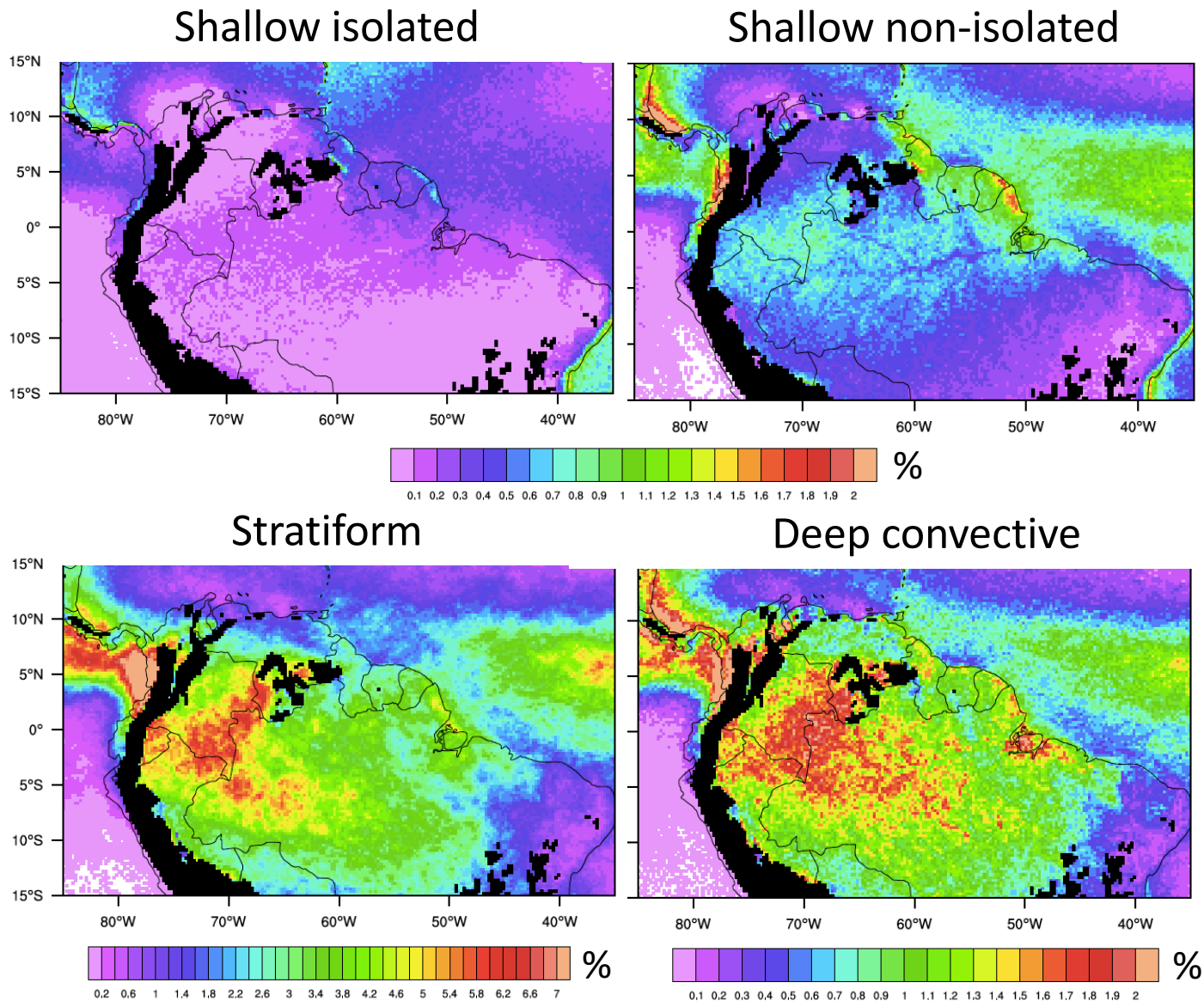
Deep convective

Courtesy of A. Funk

- Shallow isolated rain is oceanic

- Shallow non-isolated coastal preference

- Stratiform rain maximizes well inland

- Deep convective rain indicates break between sea breeze and central Amazon regimes
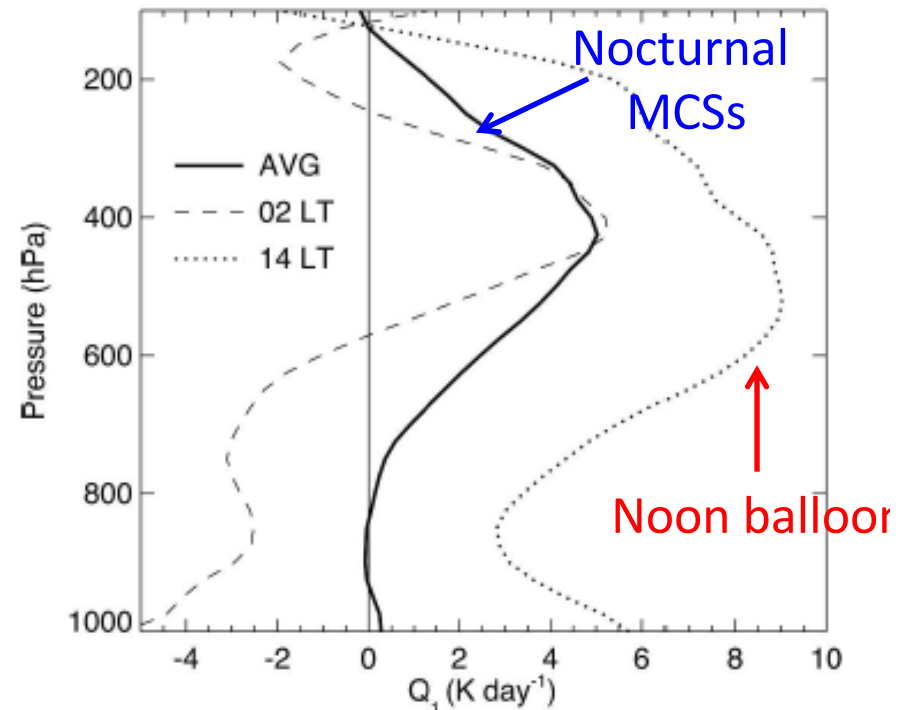
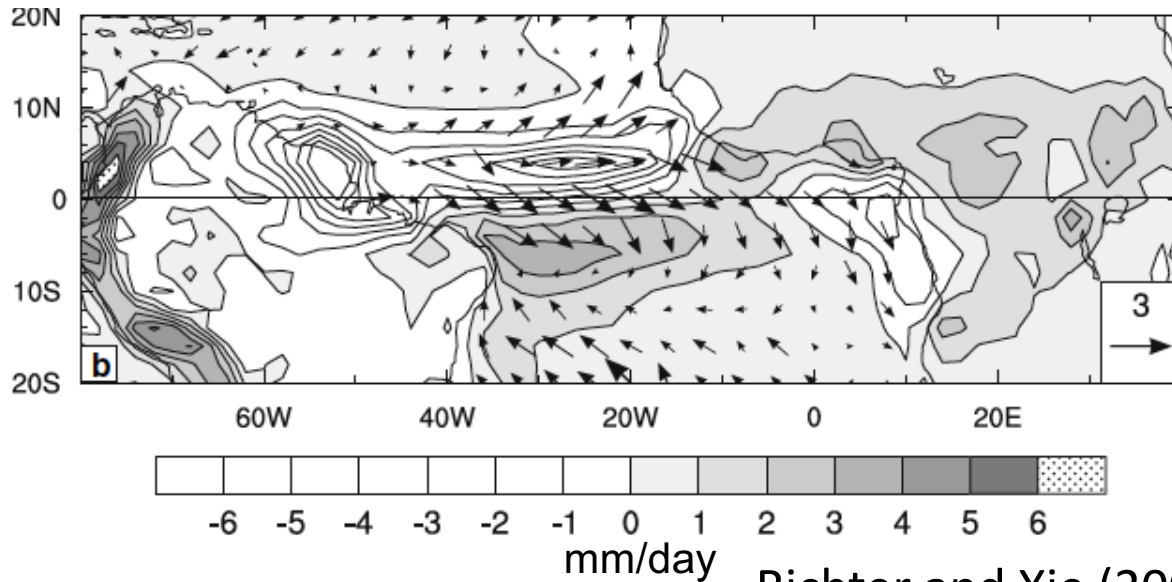# 17 February 1999, 1015 LT

+ 12 hours

Rickenbach (2004)

Variational analysis Q_1 during TRMM-LBA

Nocturnal MCSs

Noon balloon
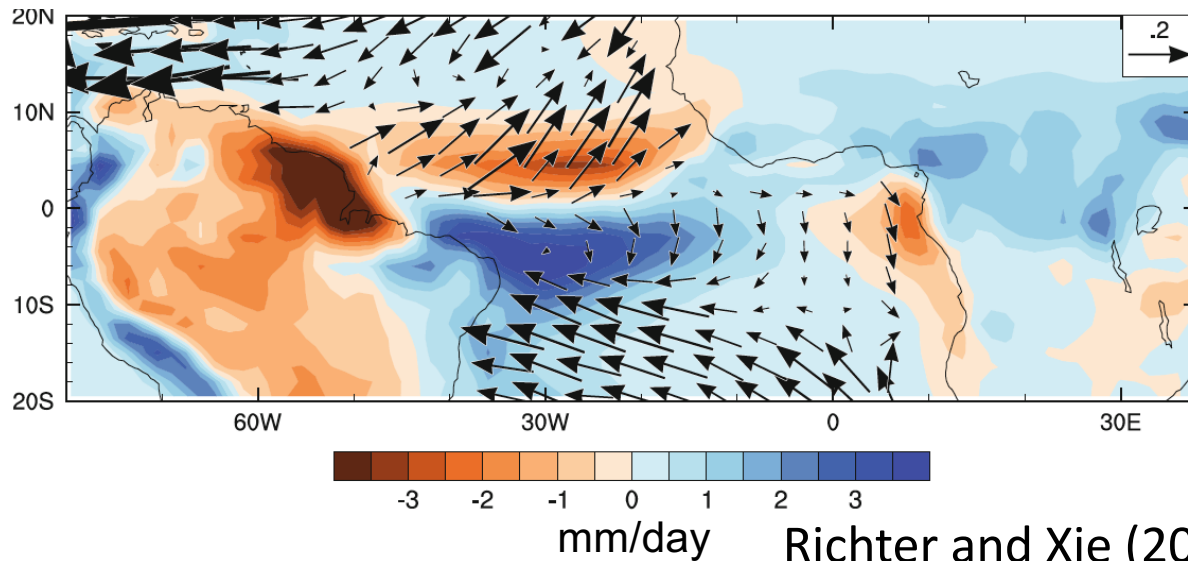
AVG
02 LT
14 LT

Schumacher et al. (2007)

- Storm type dictates the heating profile shape with MCSs being top heavy, esp. late in their life cycle

Amazon biases in climate models
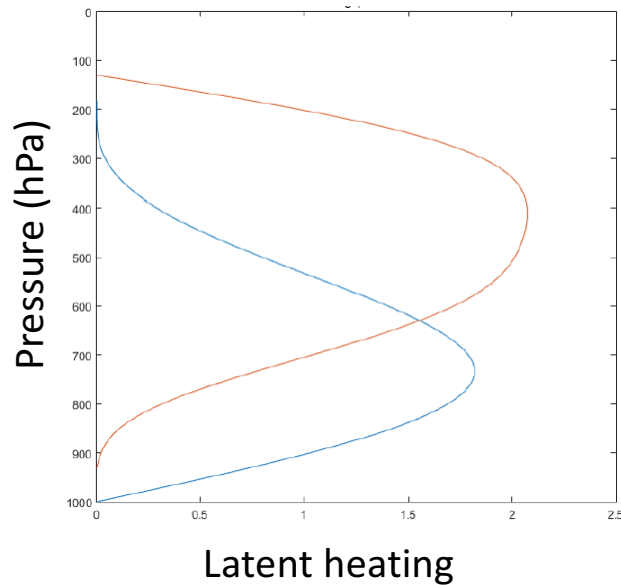

Richter and Xie (2008)

- IPCC AR4 models show a strong dry bias over the NE Amazon in MAM, which drive westerly wind biases over the Atlantic
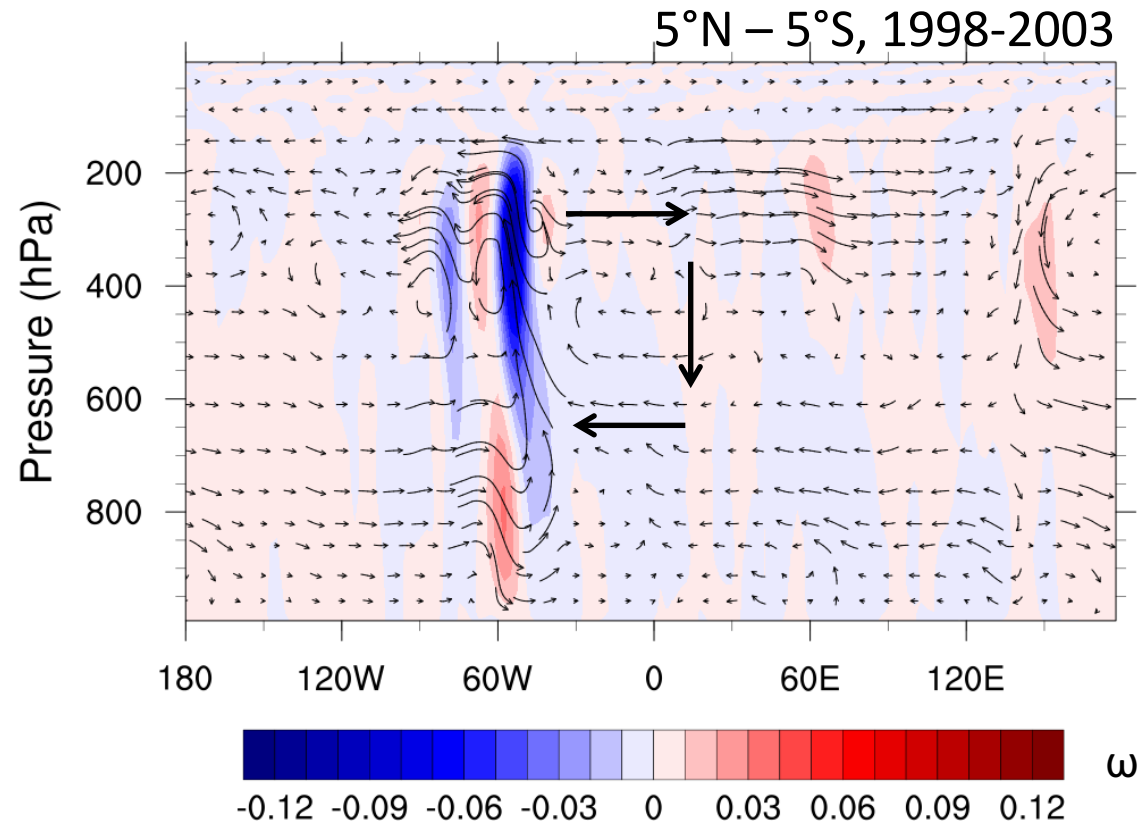

Richter and Xie (2014)

- Similar biases exist in the IPCC AR5 models. Are mesoscale processes at play?

Added heating in CAM5

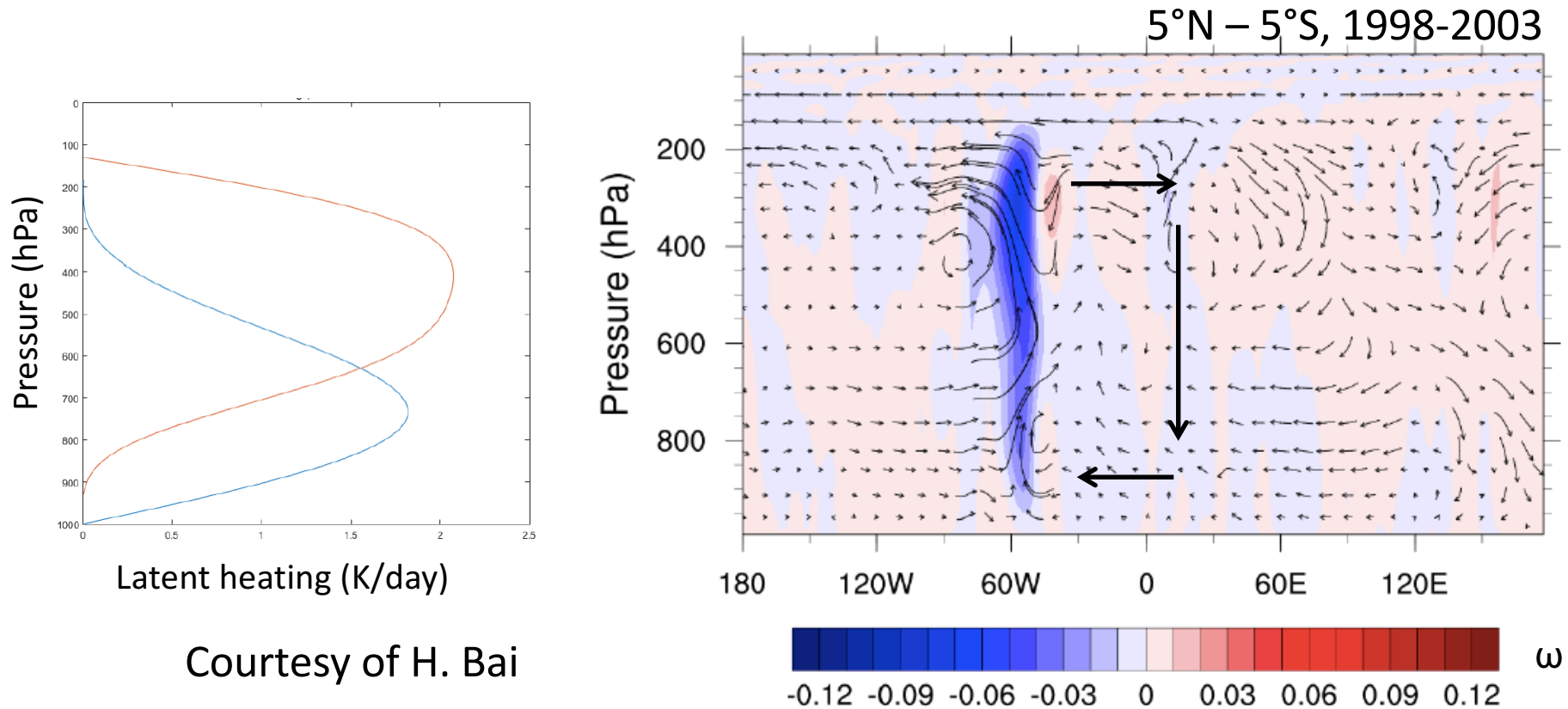5°N – 5°S, 1998-2003

Latent heating

Courtesy of H. Bai

Added upper level heating (red curve) intermittently applied over the NE Amazon during MAM strengthens the Atlantic Walker Cell, but causes enhanced easterlies at mid levels.

Following work by Hartmann et al. 1984, Lappen and Schumacher 2012, etc.

Added heating in CAM5

5°N – 5°S, 1998-2003

Latent heating (K/day)

Courtesy of H. Bai

ω

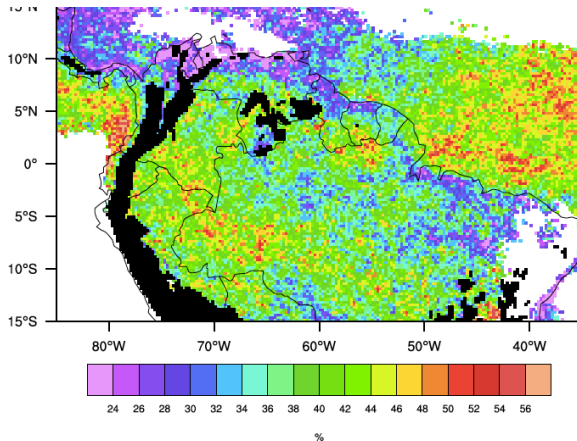-0.12 -0.09 -0.06 -0.03   0   0.03 0.06 0.09 0.12

Additional low-level heating (blue curve) is needed to rectify the low-level westerly wind bias in GCMs.
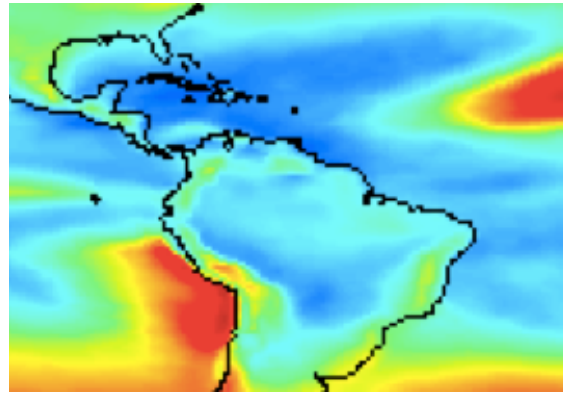
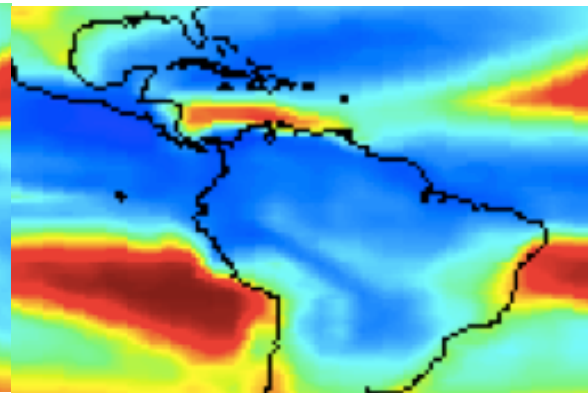Following work by Hartmann et al. 1984, Lappen and Schumacher 2012, etc.
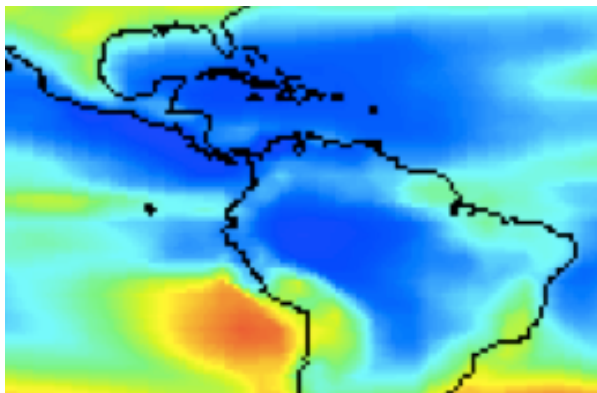
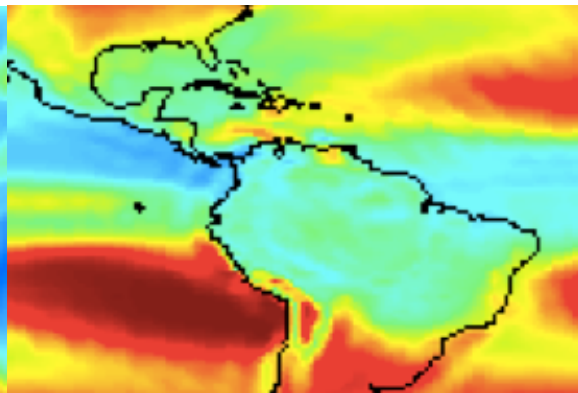# Large-scale rain in climate models (1990-2005)

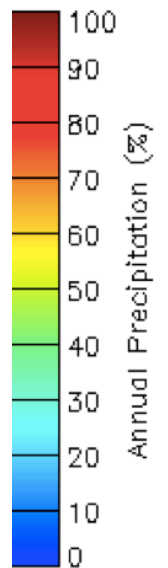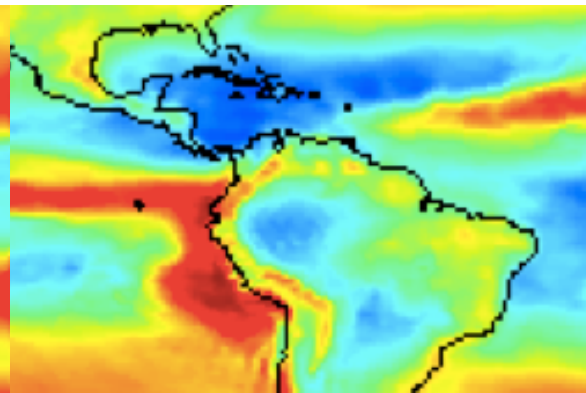
TRMM/GPM sf rain fraction
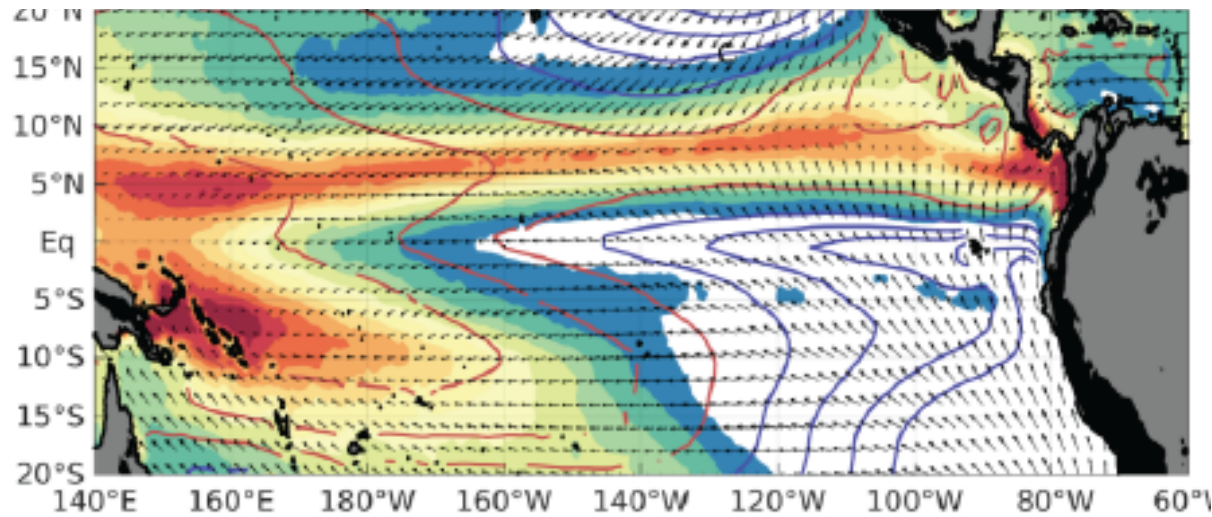
CCM4

FGOALS

GFDL

Miroc5

MRI

Courtesy of T. Aydell

CMIP5 models vary widely in large-scale rain (i.e., the rain that doesn't come from the cumulus parameterization), with little progress since Dai (2006).

Meridional overturning in the East Pacific

TRMM annual rainfall (shaded), SSTs (contours), and winds (vectors)
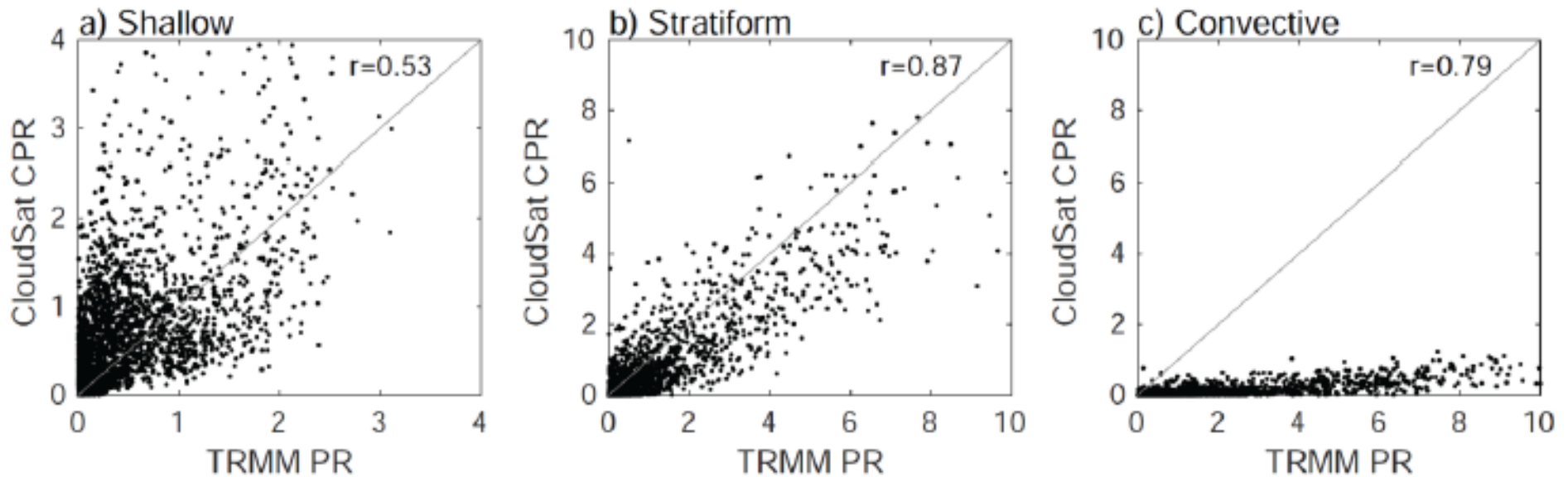

Zhang et al. (2004)

- Air rises in the ITCZ near 8-10°N in the East Pacific and transports energy across the equator at upper levels in the Hadley Cell and at lower levels in a shallow meridional circulation
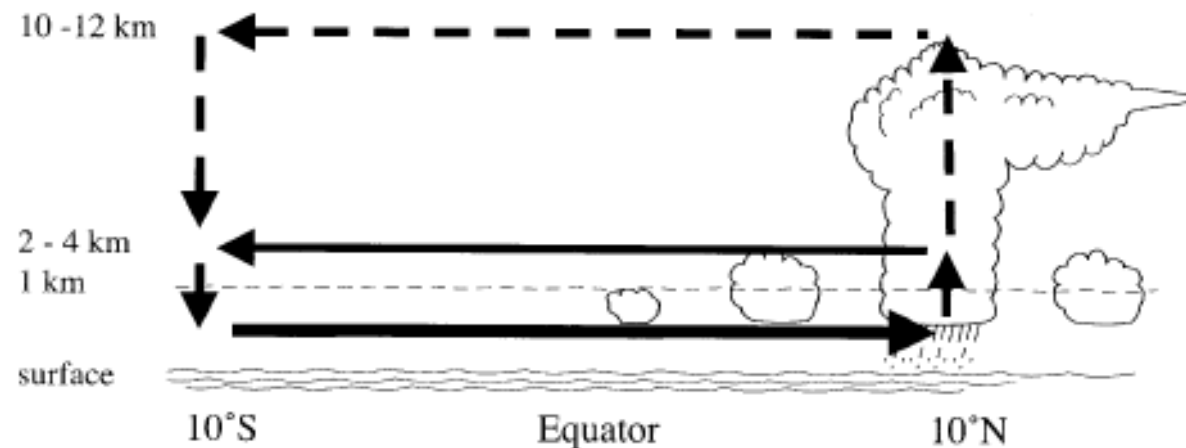
TRMM PR vs CloudSat CPR rain

a) Shallow, r=0.53; b) Stratiform, r=0.87; c) Convective, r=0.79. Axes: CloudSat CPR (y) vs TRMM PR (x).

Monthly rain amounts in the East Pacific from 10°S to 20°N show that the PR significantly underestimates shallow rain compared to the CPR while the opposite is true for convective rain. The CPR has a modest underestimation of stratiform rain. We therefore use deep convective and stratiform rain from the PR and shallow rain from the CPR for the following analysis.
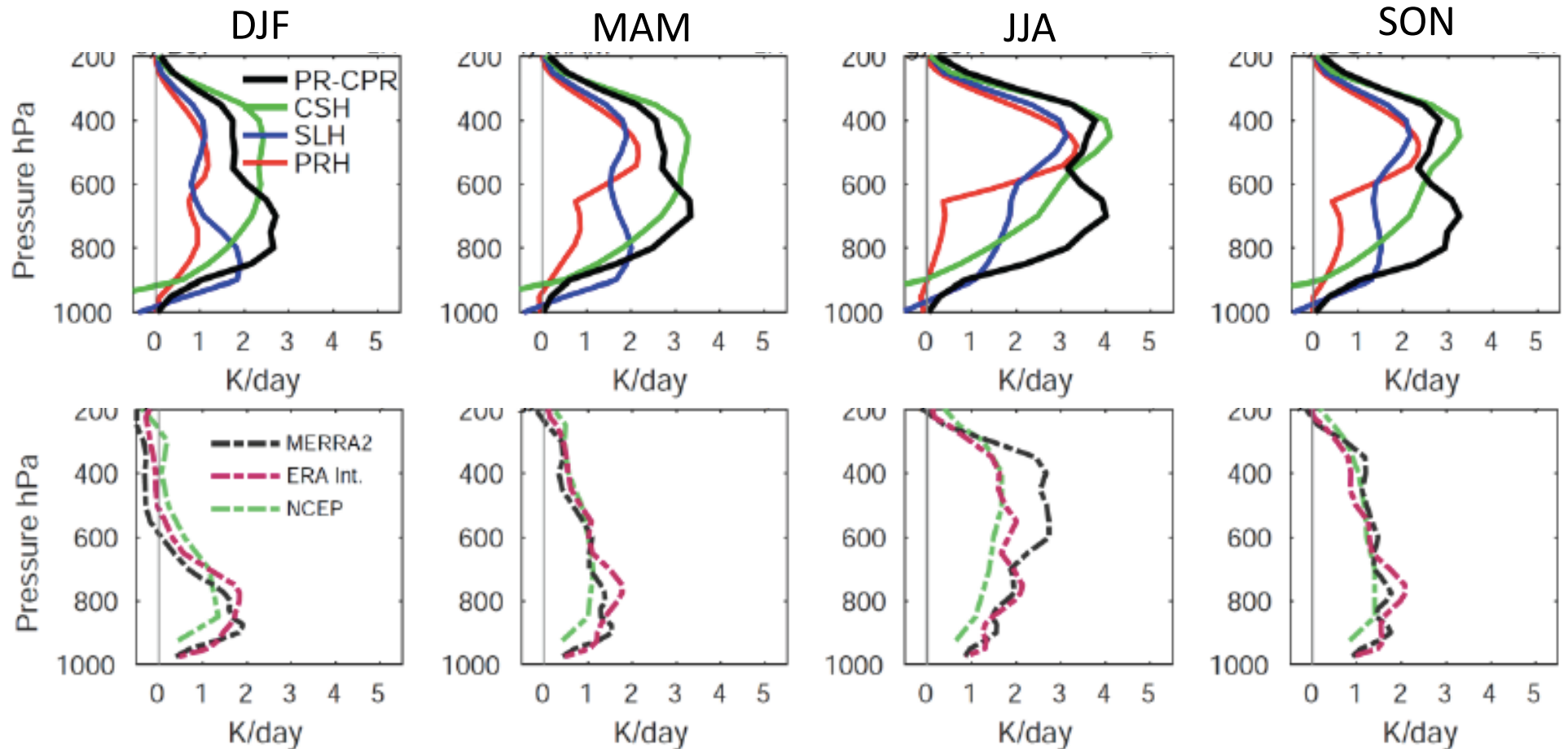
Huaman and Schumacher (submitted, JOC)

Modifications to a simple heating algorithm

TRMM convective

TRMM stratiform
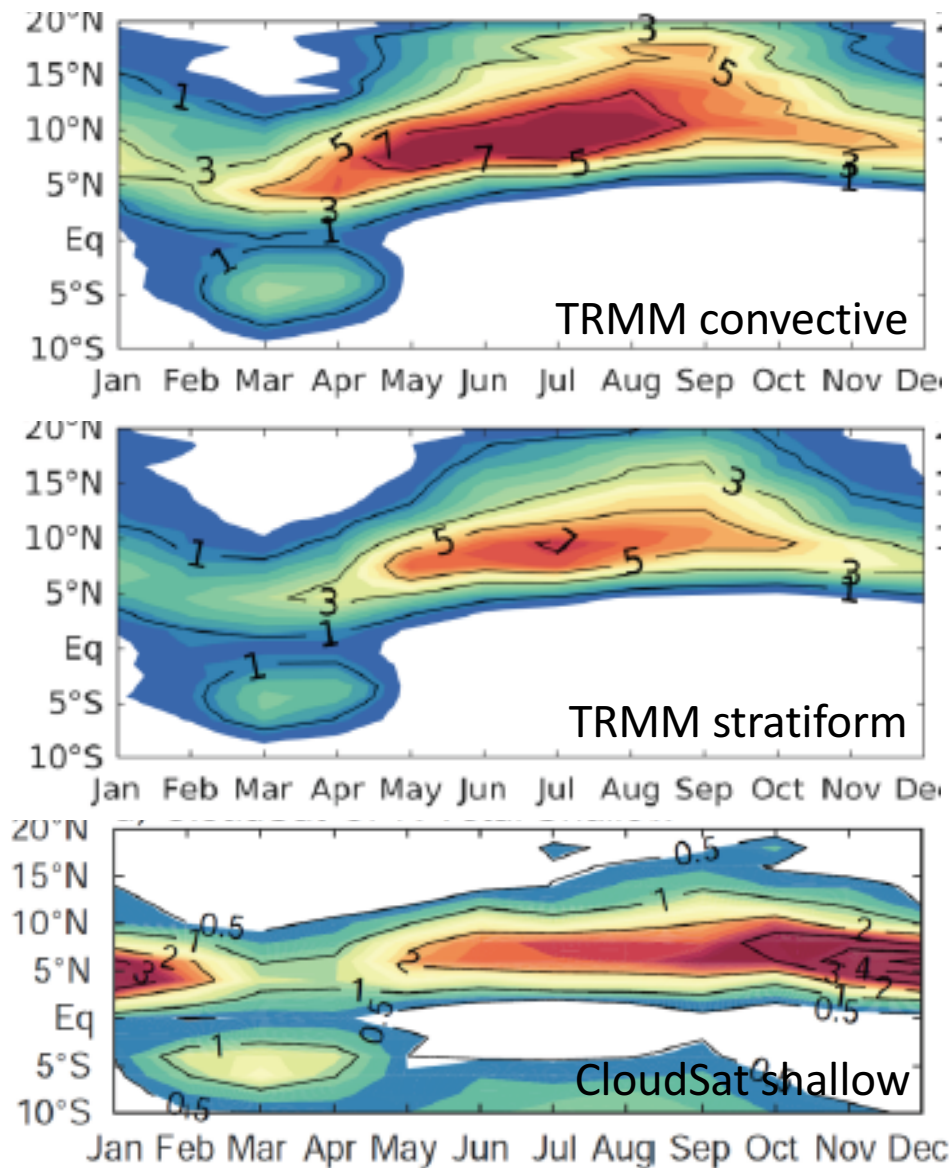
CloudSat shallow

- Following Schumacher et al. (2004), a simple look-up table with an added shallow heating profile was applied to seasonal rainfall in the East Pacific ITCZ
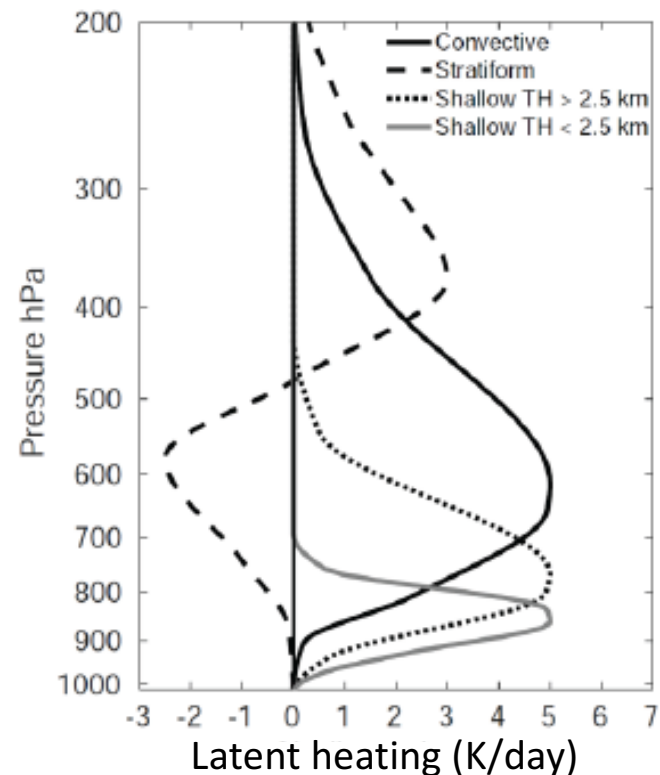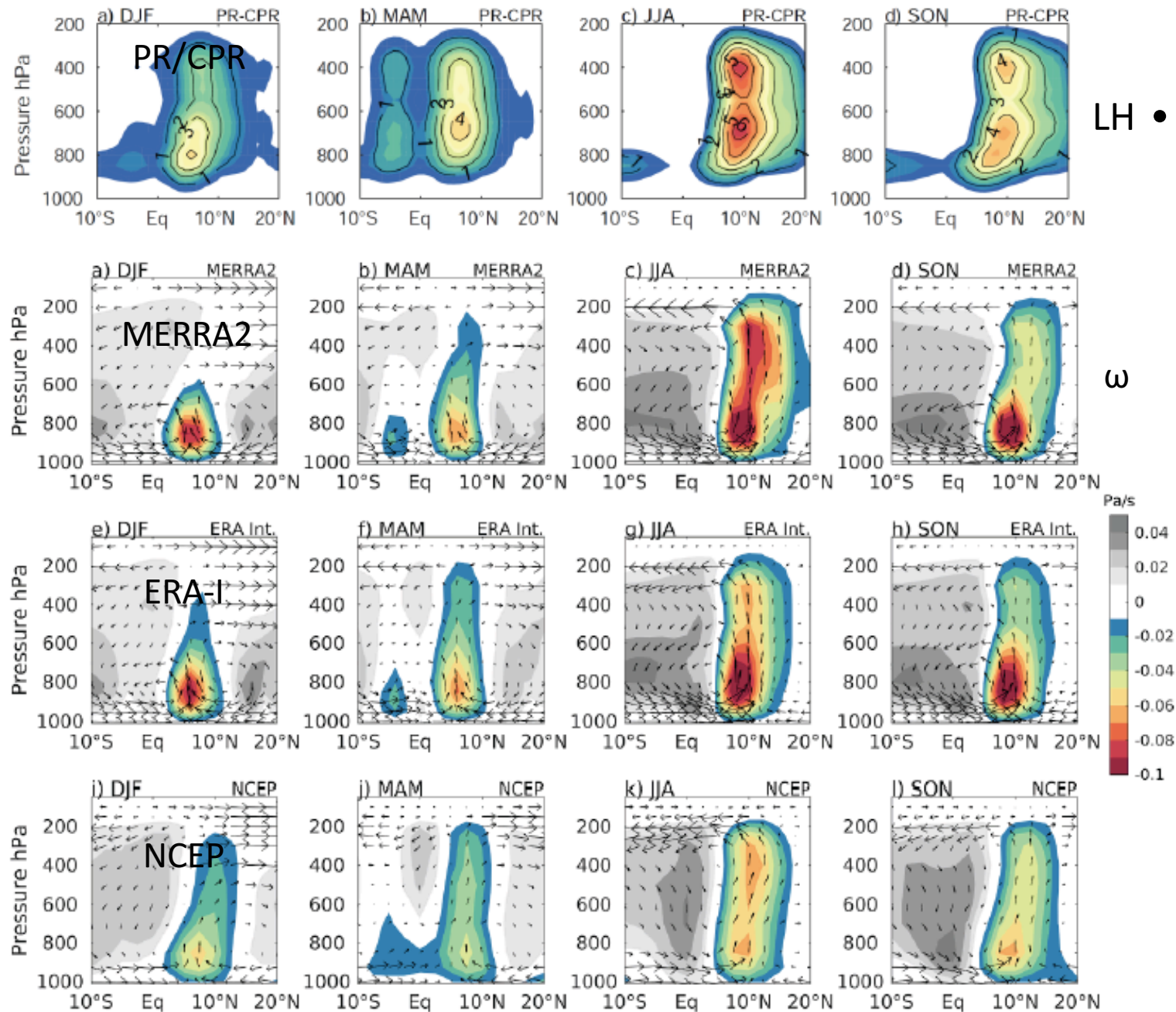
TRMM PR+ LH vs reanalysis Q_1 in EP ITCZ

The added low-level heating from CloudSat shallow convection is dominant in boreal winter and more consistent with reanalyses. However, reanalyses miss upper level heating year round.
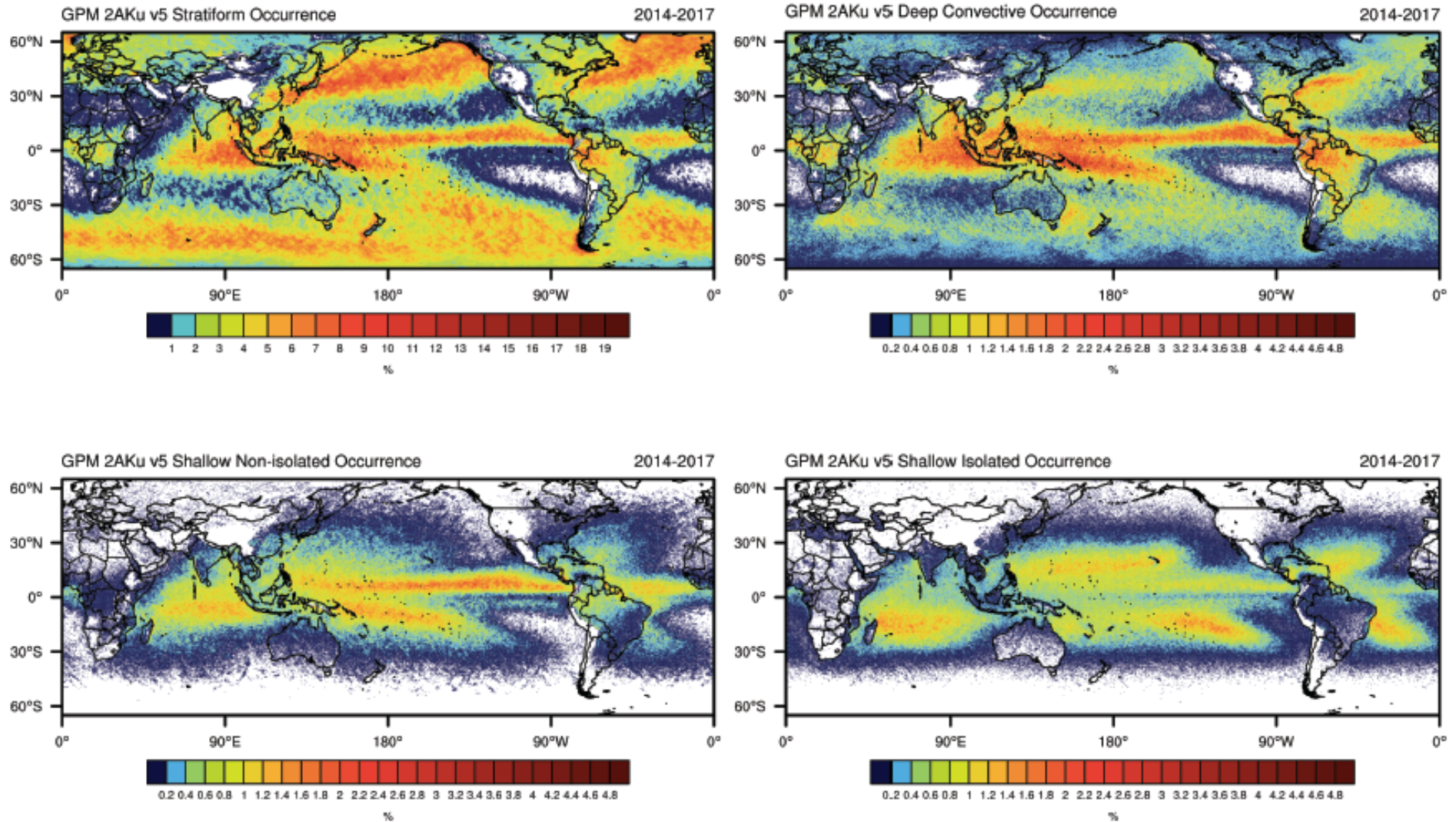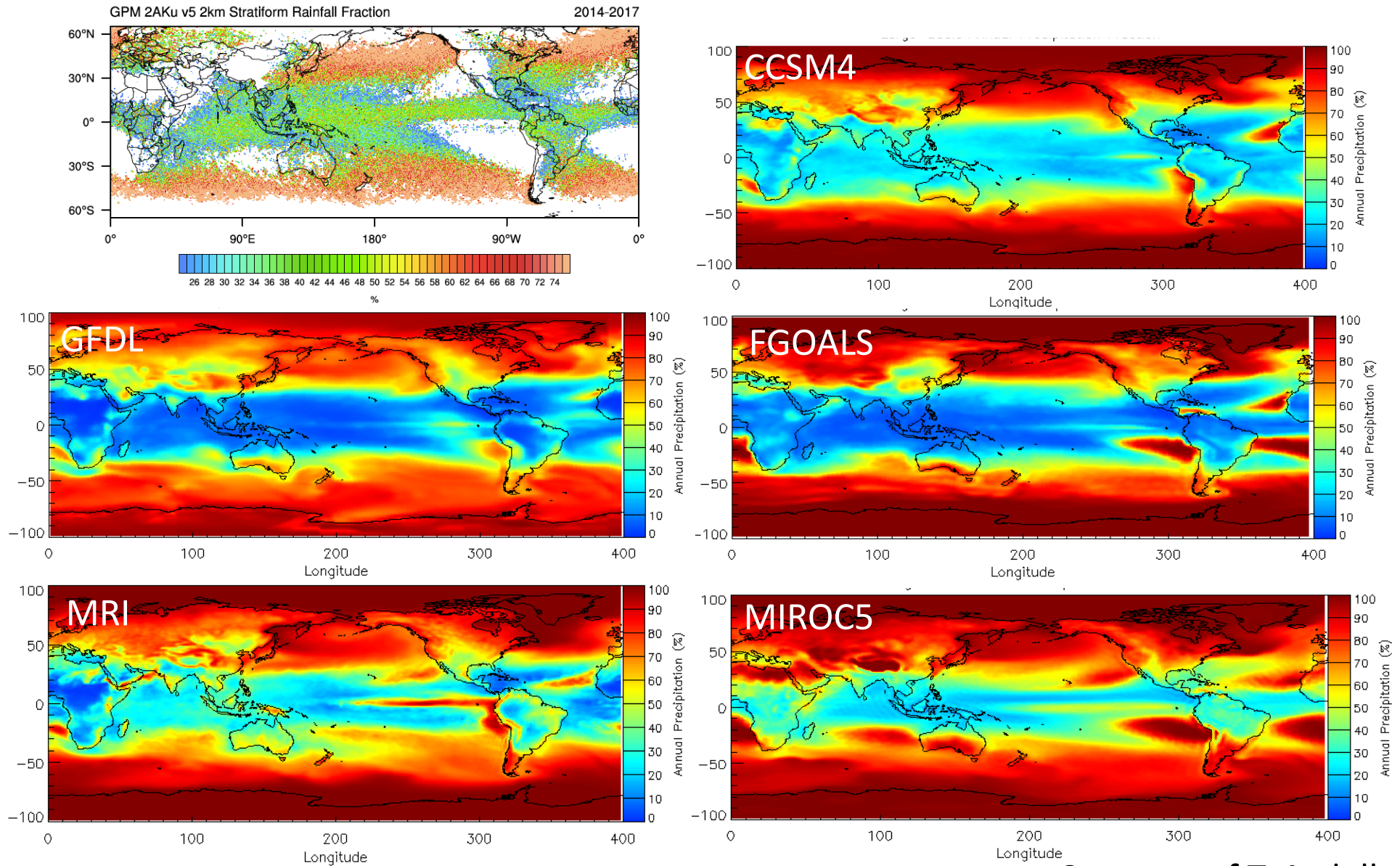
DJF   MAM   JJA   SON

PR/CPR

MERRA2

ERA-I

NCEP

LH

ω

- Ability of reanalyses to capture details of shallow and deep meridional overturning varies significantly seasonally and between models

GPM 2AKu V5 rain types

Courtesy of A. Funk

GPM vs CMIP5 stratiform rain fractions

Courtesy of T. Aydell